Project Number 282910

ÉCLAIRE

Effects of Climate Change on Air Pollution Impacts and Response Strategies for European Ecosystems

Seventh Framework Programme

Theme: Environment

D6.3
Sectoral emission profiles for selected source sectors and countries for application in local-to-regional scale models

Part 1: Anthropogenic Emission Sectors (excl. agriculture)

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Organisation name of lead contractor for this deliverable : **NERC**

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Dissemination Level		
PU	Public	☒
PP	Restricted to other programme participants (including the Commission Services)	☐
RE	Restricted to a group specified by the consortium (including the Commission Services)	☐
CO	Confidential, only for members of the consortium (including the Commission Services)	☐

1. Executive Summary

The aim of WP6 is to provide emission patterns for model experiments on European and global scale (see WPs 7, 13, 14), with a focus on terrestrial biogenic and pyrogenic emissions, and to provide improved temporal resolution of non-agricultural anthropogenic emissions. A select number of new modelling analyses are specifically assigned to incorporate ÉCLAIRE new process understanding emerging from Component 1. Specifically, the objectives are:

- To quantify how trace gas emissions from natural, semi-natural, and agricultural ecosystems vary in response to interactions of weather and climate, atmospheric CO_2 burden and N deposition, vegetation and soil carbon and nitrogen dynamics, and land use/land cover change
- To provide improved temporal dis-aggregation of non-ecosystem, anthropogenic European (pollutant emission patterns for selected source sectors (focus of this deliverable).

The objective of this deliverable is to assess and identify data to derive temporal profiles for emissions arising from anthropogenic sources. This first part of D6.3 describes the findings specifically for temporal emission profiles on the European scale for key source sectors (road transport, other mobile sources, power generation and industrial production), based on experience on highly detailed national scale work, as well as research conducted in the frame of the EUROTRAC 2 project Generation and Evaluation of Emission Data (GENEMIS) and, more recently, in EU funded research projects such as MACC, MEGAPOLI etc.

The aim is to derive robust profiles by sector and, where data availability allows, sub-sector representing the timing of emissions (hourly, daily, monthly or seasonal), while the priority is on using regularly generated, openly accessible national and European statistics. The findings of this deliverable shall enable modellers in ÉCLAIRE to implement these profiles and run models for a wide range of years/scenarios.

The findings summarised in this deliverable are the results of reviewing the state-of-the-art of methods for the temporal disaggregation of anthropogenic emission data, as well as the data resources identified that are available for and accessible to atmospheric modellers to improve the temporal emission profiles used in models to date. While a comprehensive, bottom up compilation of temporal factors for all sectors and European countries was beyond the scope and resources available for this work, the results will help to focus further research and - by testing new temporal profiles developed based on this deliverable at high spatial resolution - contribute to assessing the impact and relevance of investing into temporal emission profiles.

2. Objectives

The objective of this deliverable is to assess and identify data to derive temporal profiles for emissions arising from anthropogenic sources. This first part of D6.3 describes the findings specifically for temporal emission profiles on the European scale for key source sectors (road transport, other mobile sources, power generation and industrial production), based on experience on highly detailed national scale work, as well as research conducted in the frame of the EUROTRAC 2 project Generation and Evaluation of Emission Data (GENEMIS) and, more recently, in EU funded research projects such as MACC[1], MEGAPOLI[2] etc.

The aim is to derive robust profiles by sector and, where data availability allows, sub-sector representing the timing of emissions (hourly, daily, monthly or seasonal), while the priority is on using regularly generated, openly accessible national and European statistics. The findings of this deliverable shall enable modellers in ÉCLAIRE to implement these profiles and run models for a wide range of years/scenarios.

The core hypothesis for this work is that - in particular for the high resolution atmospheric chemistry transport modelling on the regional to local scale (i.e. in ECLAIRE, the study areas in Scotland, the Netherlands and the Po Valley) - temporal emission profiles are relevant parameters to improve the representation of modelled vs. observed ambient concentrations and depositions of air pollutants. At a horizontal resolution of 5 km x 5 km or 1 km x 1 km, the time steps of models need to be set to represent the local dispersion and short-range chemical transformation, hence the location as well as the timing of emissions may play a larger role than for instance at 50 km x 50 km resolution on regional/European scale (where emissions in the model grids will be more uniformly mixed).
The focus on readily accessible data reflects the needs of modellers, where one-off datasets and data which are incomplete or not regularly generated require substantial additional efforts to scale or process input data for atmospheric models.

3. Activities

As a first step, existing information has been reviewed, taking into account the following key data sources:

- Final results from the EUROTRAC 2 sub-project on *Generation and Evaluation of Emission Data* (GENEMIS[3]), published in Friedrich and Reis (2004)
- The book chapter *Temporal and Spatial Resolution of Greenhouse Gas Emissions in Europe* by Reis et al. (2008)
- The EU FP7 MACC deliverable report D_D-EMIS_1.3 *Description of current temporal emission patterns and sensitivity of predicted AQ for temporal emission patterns* (Denier van der Gon et al., 2011)
- Publications by Menut et al. (2012) *Impact of realistic hourly emissions profiles on air pollutants concentrations modelled with CHIMERE* and Mues et al. (2014) *Sensitivity of air pollution simulations with LOTOS-EUROS to the temporal distribution of anthropogenic emissions*.

[1] http://www.copernicus-atmosphere.eu/
[2] http://megapoli.dmi.dk/
[3] http://genemis.ier.uni-stuttgart.de/

Based on the evaluation of the information collated from these sources, as well as research conducted earlier for the UK, a list of priority sectors was set for which, in a second step, suitable data sources for temporal profile generation were to be identified.

4. Results

General approach

As a key result, it emerged early on in the review of existing literature and data, that very little research has been conducted since the days of EUROTRAC 2 and GENEMIS. This is in so far surprising, as atmospheric models have been constantly improved with regard to process understanding, spatial resolution, meteorological parameters and chemical mechanisms. However, emissions, which present a key input to atmospheric models (and are a substantial contributor to uncertainties of model results), seem to have primarily seen improvements of spatial resolution only.

Most atmospheric emission inventories do still not provide any temporal profile information. In the UK, the Department for Environment, Food and Rural Affairs (Defra) is currently funding work to generate temporal profiles for key sectors of the UK National Atmospheric Emission Inventory (NAEI), however, to date the results of this work is not yet openly available. As one of the most comprehensive global emission datasets, the EDGAR[4] inventory, does not currently provide temporal profile data, but has previously used a set of profiles based on GENEMIS and LOTOS results (Fig. 1-3)

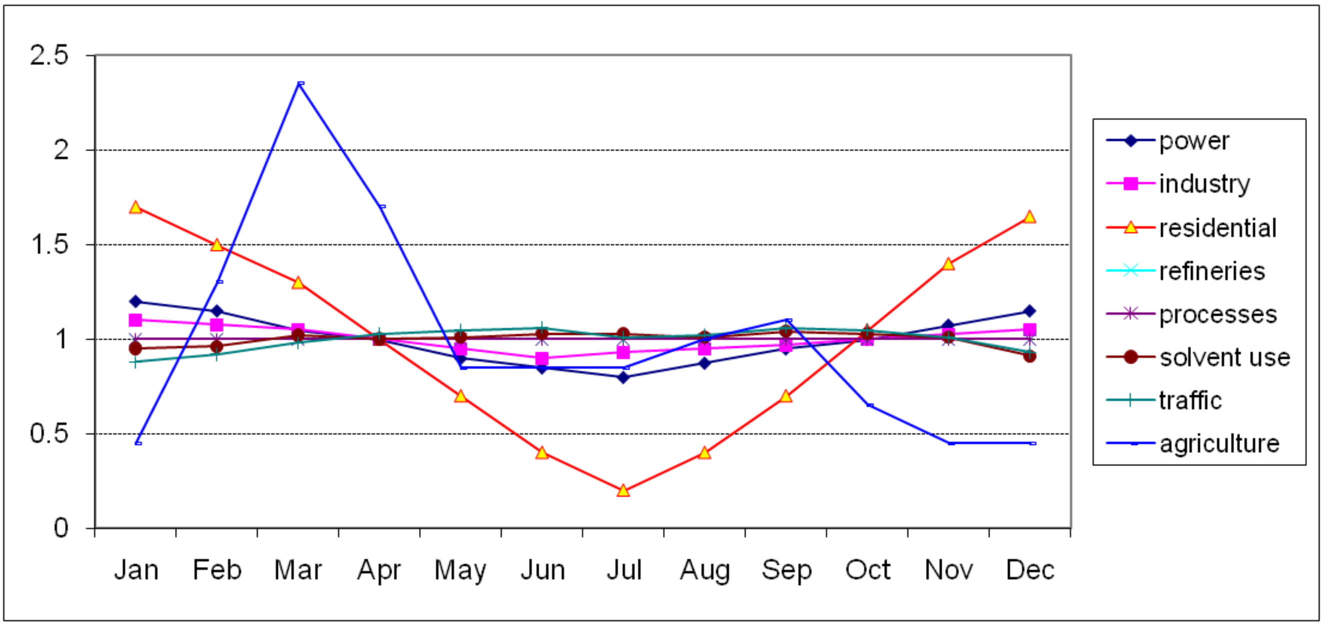

Fig. 1. Temporal variation of anthropogenic sources - Dataset compiled by TNO-MEP for TROTREP/POET (monthly temporal variation)
Source: http://themasites.pbl.nl/tridion/en/themasites/edgar/documentation/content/Temporal-variation.html

[4] http://edgar.jrc.ec.europa.eu/

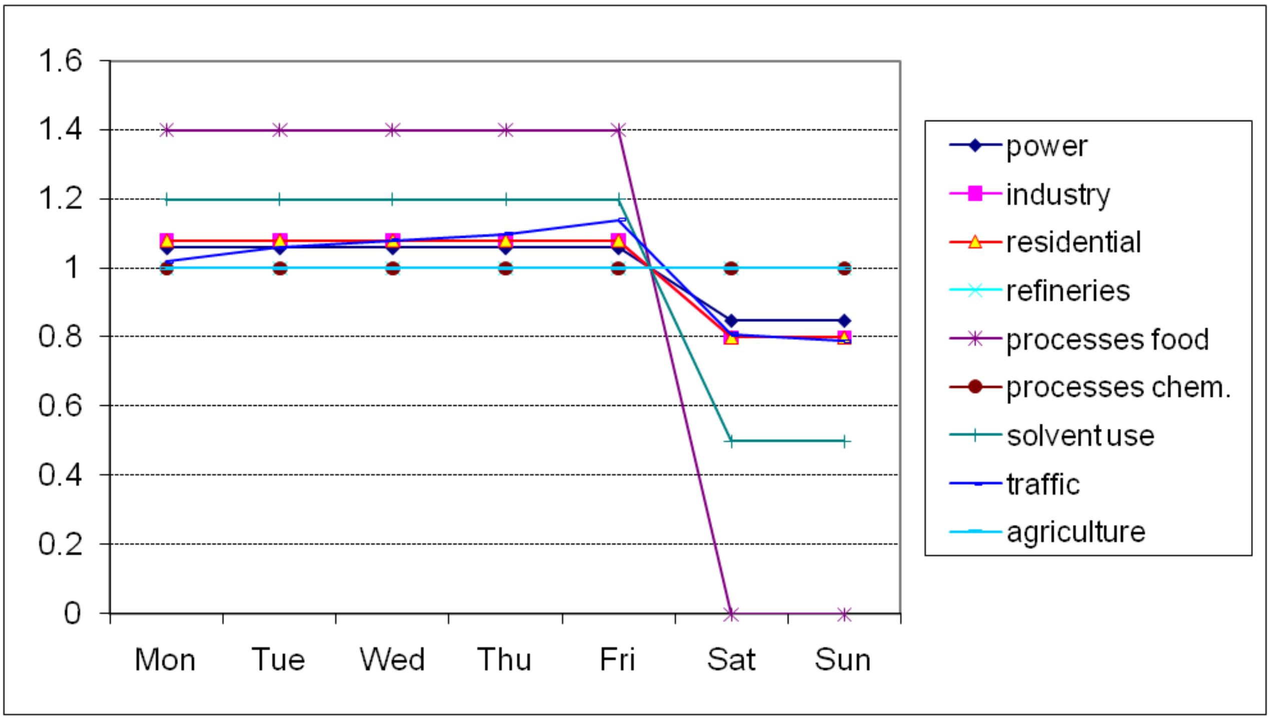

Fig. 2. Temporal variation of anthropogenic sources - Dataset compiled by TNO-MEP for TROTREP/POET (weekly temporal variation)
Source: http://themasites.pbl.nl/tridion/en/themasites/edgar/documentation/content/Temporal-variation.html

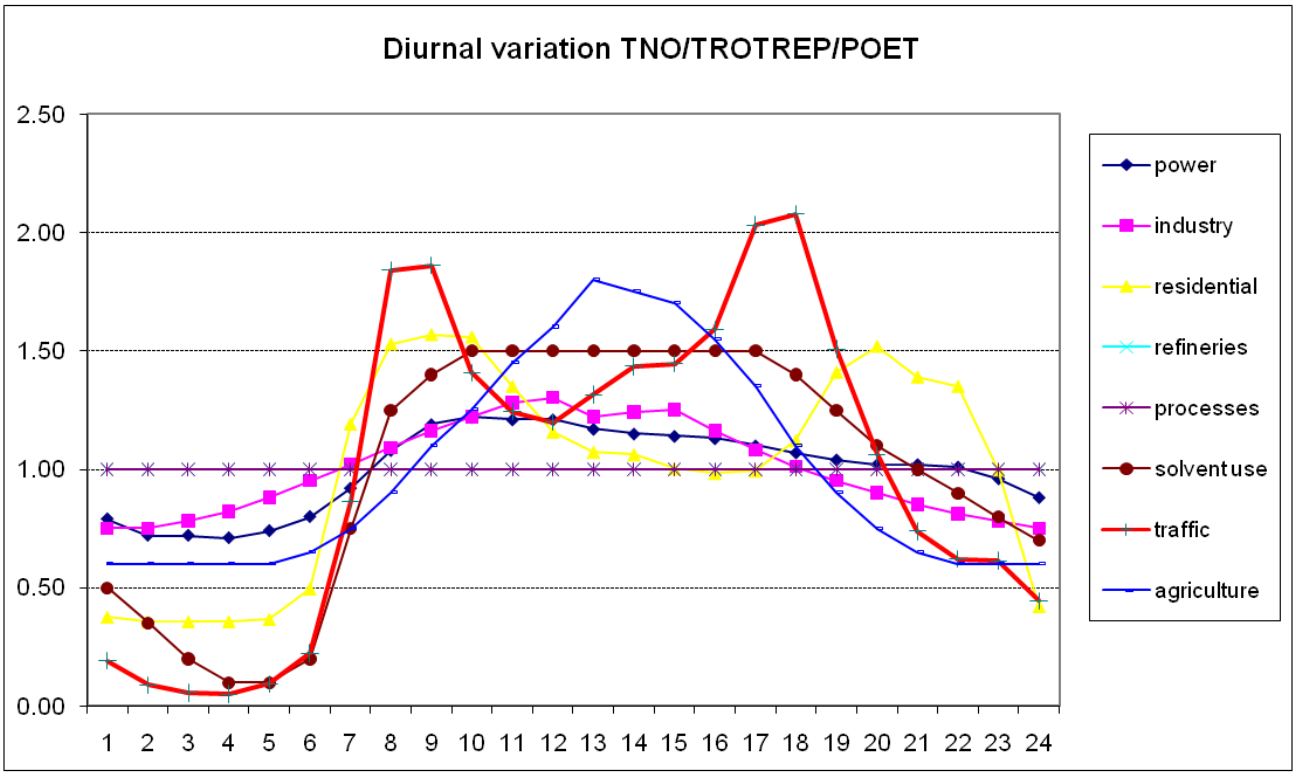

Fig. 3. Temporal variation of anthropogenic sources - Dataset compiled by TNO-MEP for TROTREP/POET (diurnal temporal variation)
Source: http://themasites.pbl.nl/tridion/en/themasites/edgar/documentation/content/Temporal-variation.html

Figs. 1 - 3, which are based on a GENEMIS and other datasets, illustrate well how different sectors show variability in their emissions over the year, week and day. Current atmospheric chemistry transport models typically already include some representation of temporal variability, often based on the very same datasets.

Accounting for the temporal distribution of emissions on a national or local scale requires a substantial amount of data. Thus, a first step is to identify the main drivers of the temporal patterns of the relevant emissions and strike a balance between a perfect, real-time temporal allocation and a feasible, cost-effective approach which will deliver a substantial improvement over the current situation (i.e. no distinct temporal distribution, respectively potentially outdated information) while being manageable on a regular basis (accessibility and regular availability from open sources).

The following Table 1 lists the main influencing factors for the temporal distribution of emissions for selected source sectors and pollutants, being by no means comprehensive and complete, but showing that a few factors can actually inform about the distribution of different pollutants across sectors. For this study, meteorological parameters such as temperature, rainfall and suchlike have been excluded, keeping the focus of the sensitivity runs on the influence of purely anthropogenic activities on the emission distribution.

Table 1. Overview of main influencing factors for the temporal distribution of emissions for selected source sectors and key pollutants

Source sector	**NH_3**	**NO_x**	**SO_2**	**NMVOC**
Large Combustion Plants (SNAP 1/3)	-	power/heat demand, temperature		-
Residential and Commercial Com-bustion (SNAP 2)	-	power/heat demand, temperature		-
Industrial Production Processes (SNAP 3/4)	-	shift routines, seasonality of demand		
Solvent Use (SNAP 6)	-	-	-	*paint/solvent application routines, temperature*
Road Transport (SNAP 7)	-	daily/weekly/seasonal transport demand patterns	-	daily/weekly/seasonal transport demand patterns
Other Mobile Sources (SNAP 8)	-	*daily/weekly/seasonal transport demand patterns*		*daily/weekly/seasonal transport demand patterns*
Agriculture (SNAP 10)	*fertiliser & manure application, temperature*	*fertiliser & manure application, temperature*	-	-
Natural and Biogenic Sources (SNAP 11)	*temperature*	*temperature*	-	-

Text in *italics*: source sectors not addressed in this deliverable

MACC

More recently, the EU FP7 project Monitoring Atmospheric Composition and Climate (MACC) has investigated the relevance of updating temporal emission profiles. In the Deliverable D-EMIS 1.3 (Denier van der Gon et al., 2011). The aim of this MACC deliverable report is *"... to present a representative set of currently used temporal profiles in European air quality modelling and illustrate* *its impact on emission timing. Furthermore, the impact of applying such temporal profiles … and a first example of updating and improving such temporal profiles is presented. The analysis and update of temporal profiles described here is a starting point for further work …".*

The key findings from MACC regarding temporal profiles can be summarised as follows::

- Temporal emission profiles are important to properly distribute emissions over time but the importance differs much by source sector
- Impact of temporal emission profiles on annual average concentrations over Europe is limited but…
  - near anthropogenic hot spots (major cities) it may be substantial.
  - For episodes the impact may be larger.
  - One source sector may partly compensate another (obscures real contribution).

These findings are of particular relevance for ECLAIRE for two reasons: the remark on anthropogenic hotspots may as well be applicable to the effect of large conurbations on the surrounding rural area, which means that the timing of anthropogenic emissions may affect the transport and effects of air pollution on natural and semi-natural vegetation away from the emission source region. Secondly, with episodes being a specific challenge for high ozone concentrations and their effects, the timing of ozone precursor emissions may be specifically important. Fig. 4 illustrates the basic set of temporal profiles used for the exploration of effects on model results in MACC.

In a next step, the MACC team investigated specifically the effect of improvements of temporal profiles for the power generation sector, which shows a marked seasonality, with substantial differences across Europe due to regional climates and differences in power and heat consumption patterns. An example for selected European countries is depicted in Fig. 5, which shows that (a) the variability differs substantially between northern and southern European countries, and (b) that the individual country patterns are significantly different from the average pattern.

The key findings of the MACC research can be summarised as follows:

- It is recommendable to first make educated guesses of what variation in temporal emission profiles by source sector for different countries could be expected.
- The range in indicative temporal variation could be used to do a sensitivity analysis with a regional air quality model to verify if the impact is significant enough to justify allocation of resources.
- First test cases would be residential combustion, agriculture and road traffic rush hours.
- Future improvements could come from replacing default profiles used in the models to meteorologically driven functions. Especially for e.g. residential combustion and agriculture large variations are observed between the different seasons which could depend strongly on the actual meteorology. For example if colder temperatures as a start of winter start relatively late or early in a year. This will be further investigated in the next stages of MACC.

For ECLAIRE, the main points here confirm that prioritisation is important, as well as that the long-term objective for particular sectors which show a variability driven primarily by meteorological parameters (temperature, relative humidity etc.) should focus on dynamic, meteorology-based functions. The work conducted within ECLAIRE on the temporal variability of agricultural emissions, as well as the development of the ESX are going in this direction. For this deliverable, the focus will be on **road transport** and **power generation**, as well as **residential combustion** sources.

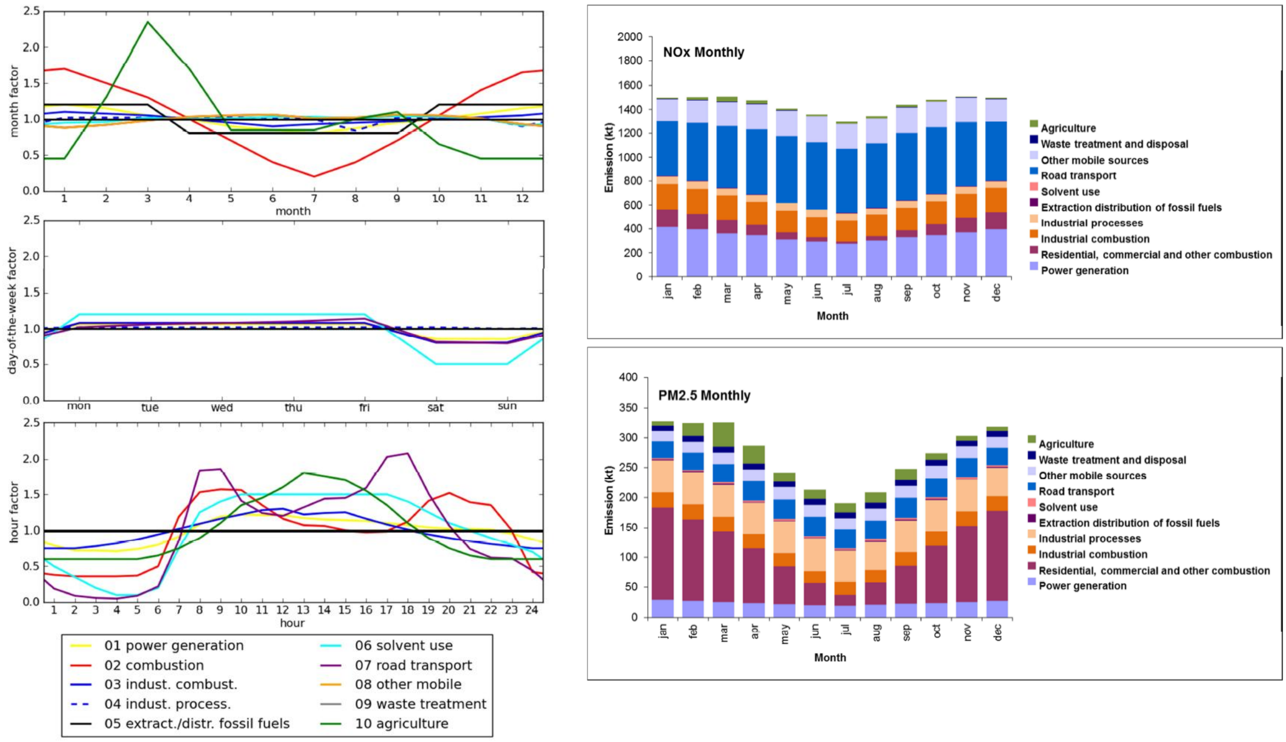

Fig. 4. Illustration of temporal profiles applied in MACC (left) and resulting monthly emissions for NO_x (right, top) and PM2.5 (right, bottom)
Source: Denier van der Gon et al. (2011)

Power generation (SNAP 1)

Fig. 5 depicts the variability of monthly emissions from the power generation sector in selected European countries, using the example of total electricity use. The patterns indicate that in Northern Europe, the electricity demand in Winter is substantially larger than during summer months, reflecting increased needs for lighting and process heat during the cold period, while for Southern European countries, the peak in the summer illustrates the electricity demand for air conditioning and other cooling processes. The electricity demand which is reflected in Fig. 5 is thus somewhat different from the consumption of primary energy carriers, e.g. natural gas (see Fig. 6), which is mainly used for cooking or direct residential/commercial heating and thus does not typically show the summer peak in Southern European countries.

The focus here is on seasonal variability, as information on diurnal variations is not readily available from open data sources. For base-load power plants, continuous operation can be assumed, however, while for peak-load plants, their operation is predominantly demand driven and is difficult to anticipate.

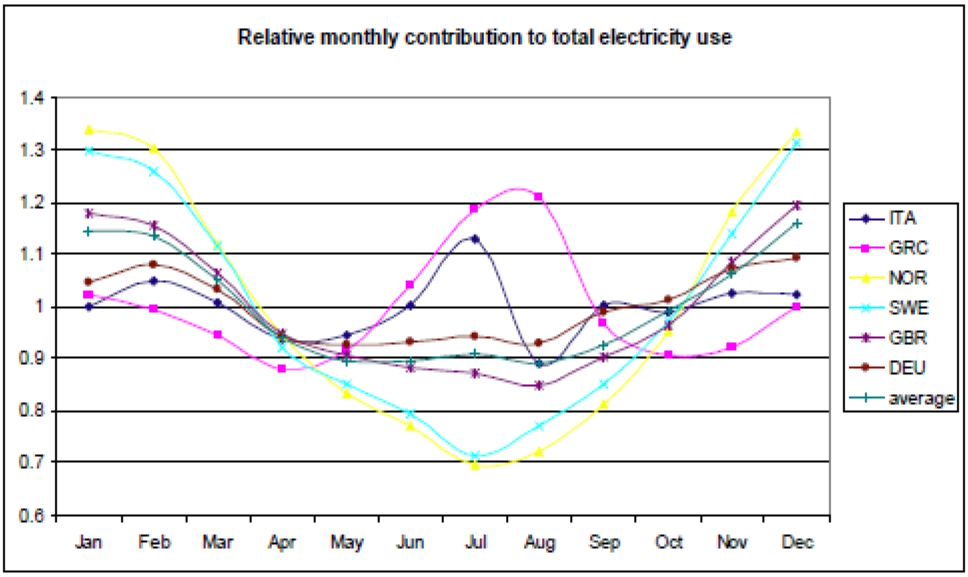

Fig. 5. Illustration of the variability of monthly temporal profiles of the power generation sector in different European countries.
Source: Denier van der Gon et al. (2011)

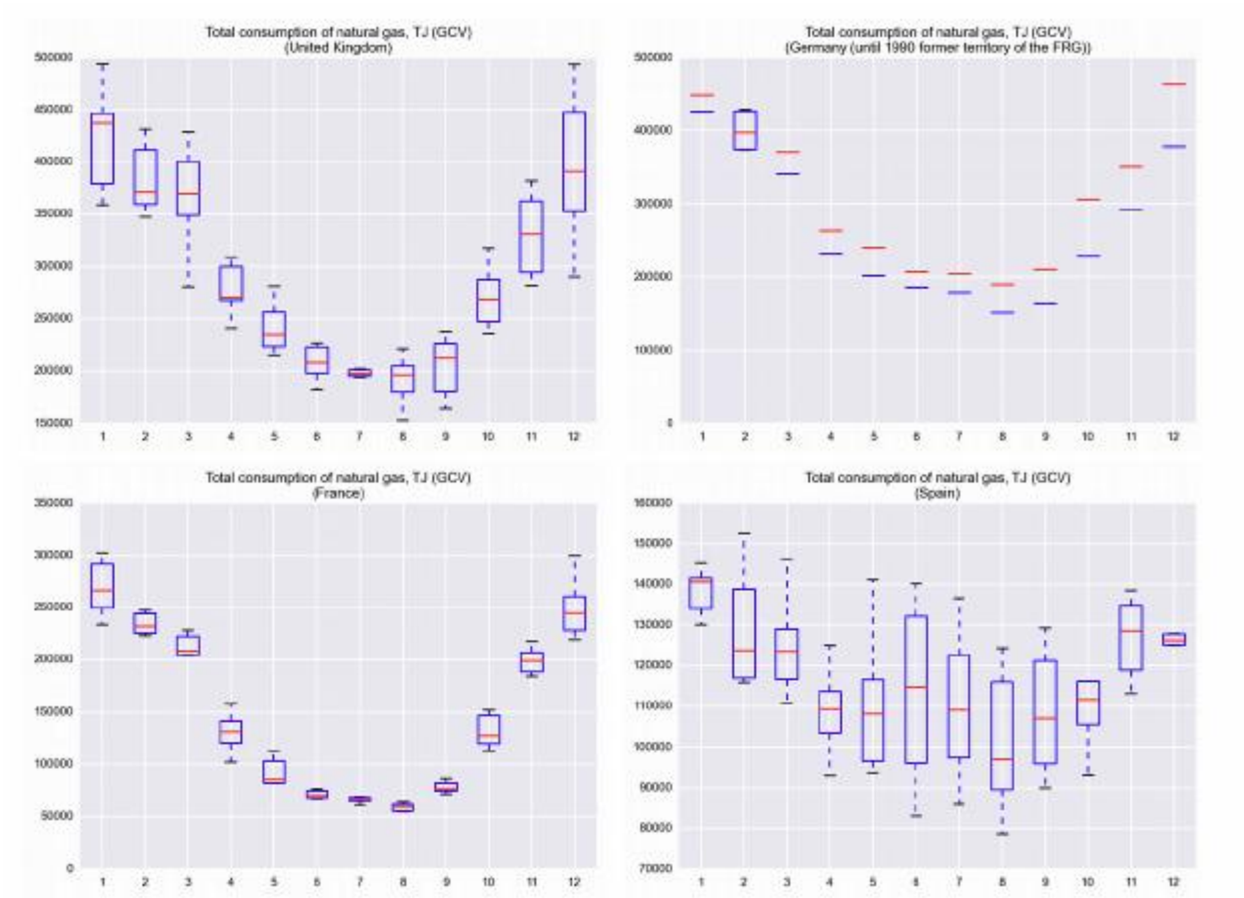

Fig. 6. Total consumption of natural gas, TJ (GCV) - monthly data available from EUROSTAT showing average over several years, as well as inter-annual variability (IS-CNG-TJ)

In this respect, the consumption of natural gas for power generation is more closely related with the degree days (see the following section on Residential Combustion). An overview of EUROSTAT data on electricity consumption in the EU27 is provided in Fig. 7, however, some caveats need to be addressed, which were already mentioned in Reis et al. (2008). While national monthly statistics of electricity consumption are readily available from EUROSTAT, these do not immediately relate to electricity generation in the same country, as due to the European electricity grid generation capacity and price developments may trigger generation in power plants in different parts of Europe. A second caveat is the increasing share of renewable energy in electricity generation, which may affect the timing and location of emissions and which cannot be immediately derived from available statistics.

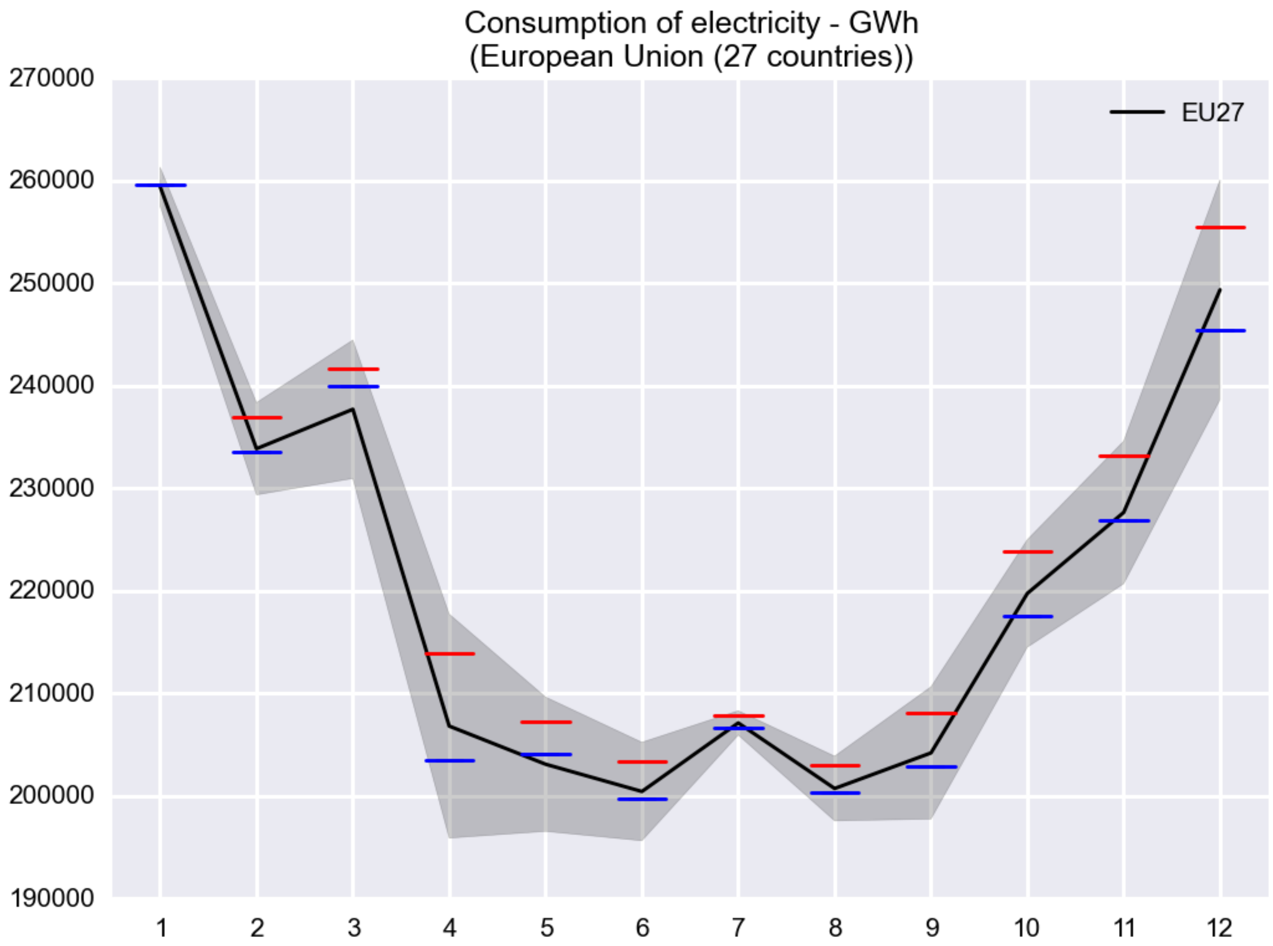

Fig. 7. Monthly consumption of electricity in GWh for the EU27 averaged over the period 2008 - 2011 showing average over several years, as well as inter-annual variability from EUROSTAT (NSA_IS-CEL)

The final caveat is related to the lack of distinction of fossil fuels on SNAP level 1, which presents a challenge as base load power plants (primarily nuclear and coal fired) and peak load (usually gas fired) plants have very different operating patterns and thus their temporal emission profiles are equally different. This last aspect becomes evident when conducting a more detailed analysis for the UK, based on available statistics from the UK Department for Business, Innovation & Skills (Fig. 8.) While base load power generation (represented by coal) correlates well with average ambient temperature over the UK (R^2 = 0.79), peak load generation (represented by gas) shows only weak correlation with temperature (R^2 = 0.19) for example in the year 2006.

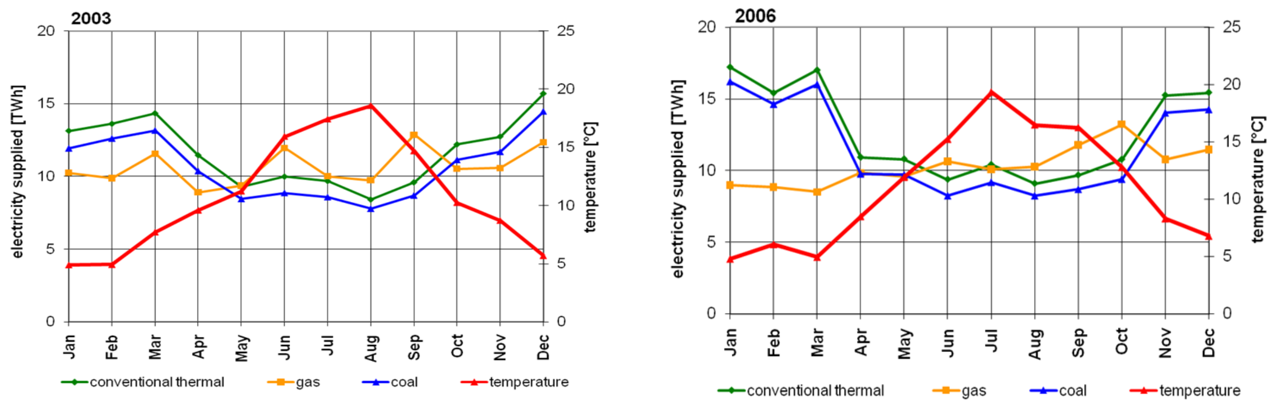

Fig. 8. Analysis of electricity generation by gas and coal fired power plants in the UK for two different years based on data from the UK Department for Business, Innovation & Skills (https://www.gov.uk/government/collections/total-energy-statistics

However, Fig. 8 does illustrate as well that - at least for the UK - coal fired power plants in 2003 and 2006 determined the shape of the temporal profile, while gas fired generation did not show a distinct seasonality. Hence, the uncertainty introduced by using one temporal profile factor for the whole of SNAP 1 may be regarded as minor overall, yet the contribution of a local emission source (e.g. a gas fired power plant) and its specific temporal emission pattern may affect the high resolution modelling results in an area more profoundly.

Residential combustion (SNAP 2)

Residential combustion has been one of the sectors on which MACC did focus and the results of an initial comparison have been published by Mues et al. (2014). The approach tested is based on the use of degree days and is the currently best available approach for this sector, as the use of residential (and commercial) process energy is strongly correlated with outside temperature. Fig. 9 shows both the seasonal and the diurnal variability for two different locations as presented in Mues et al. (2014).

Based on these preliminary results, a search for an easily accessible source for heating degree day data for the whole of Europe was conducted. EUROSTAT provides data on NUTS2 level, which presents the currently most useful spatial resolution. Fig. 10 illustrates the available time series as well as the mean degree days for 4 selected EU Member States, while the full dataset is available for download at EUROSTAT[5], respectively has been collated for use by modellers in a CSV file. The final preparation and format for data delivery will be discussed with ECLAIRE modellers on a by case basis.

[5] http://epp.eurostat.ec.europa.eu/portal/page/portal/product_details/dataset?p_product_code=NRG_ESDGR_A

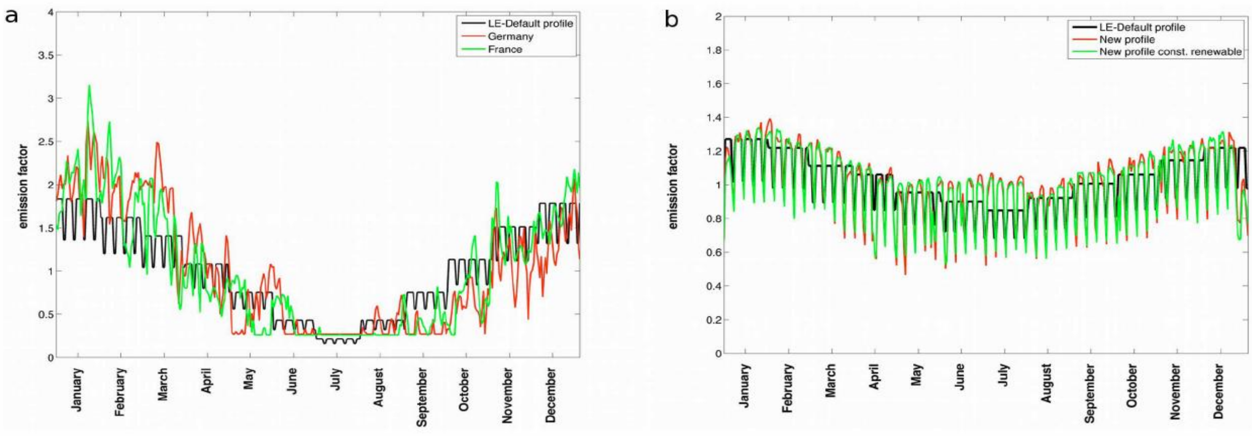

Fig. 9. Comparison between the new and the default seasonal (daily) emission factors for SNAP2 (a) retrieved from model grid cells located in Germany (longitude approximately 10 E, latitude approximately 52.5 N) and in France (longitude approximately 2.75W, latitude approximately 43.75 N) and for SNAP1 (b) for Germany.
Source: Mues et al. (2014)

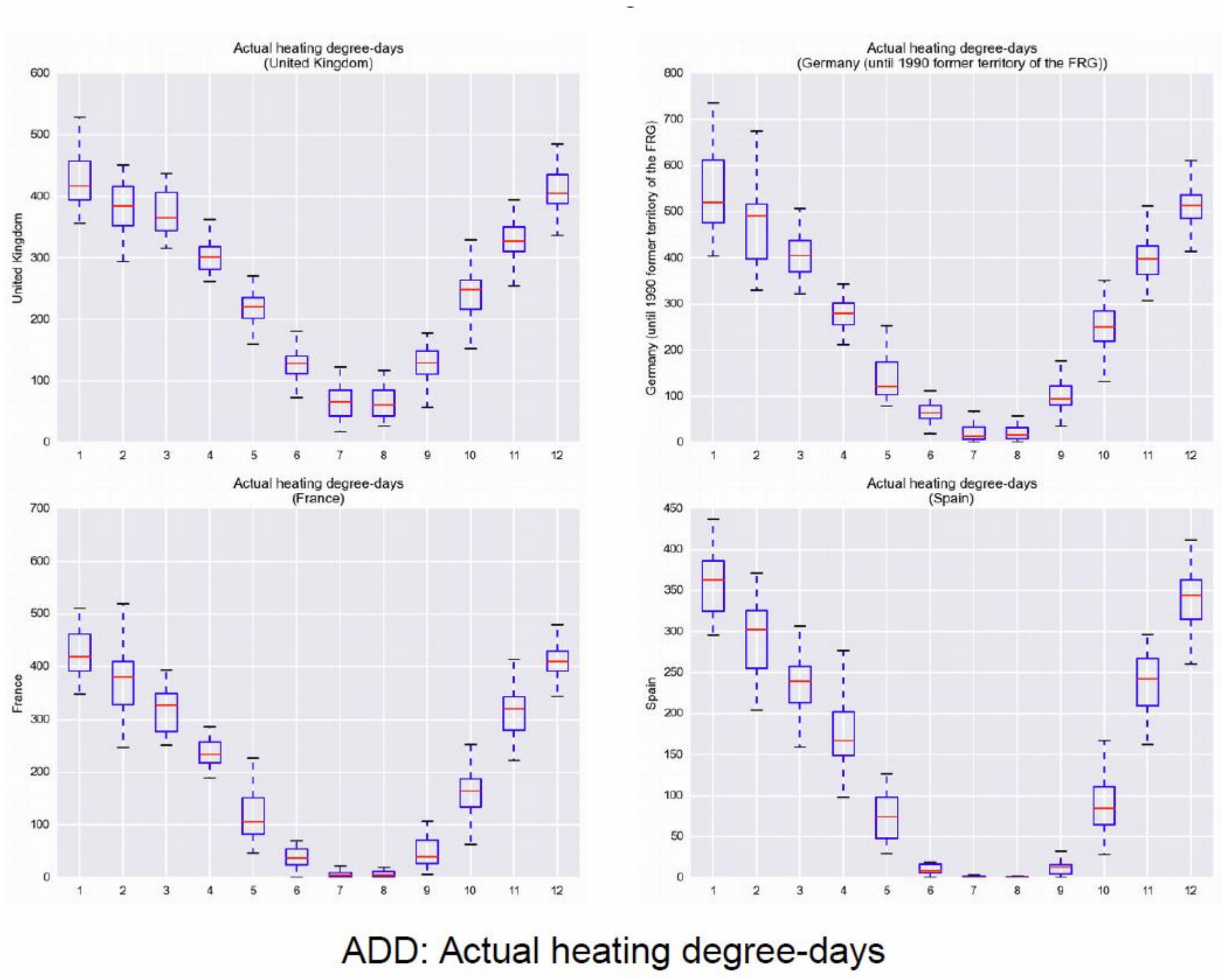

Fig. 10. Heating degree-days by NUTS 2 regions - monthly data available from EUROSTAT showing average over several years, as well as inter-annual variability

As atmospheric chemistry transport models require detailed meteorological input data, the heating degree days will likely be best generated directly in the meteorological model, however. EUROSTAT data could be used as an alternative when no meteorological input data are available.

Industrial production (SNAP 3/4)

Industrial production patterns affect emissions both from industrial combustion (SNAP 3) and industrial production processes (SNAP 4). Compared to power generation, residential combustion and road transport, emissions from these two sectors do not represent a large contribution to total emissions.

The sectors are very diverse with different processes and production patterns, driven mainly by consumer demands and economic climate (see Fig. 11), while seasonal variability is low (Fig. 12).

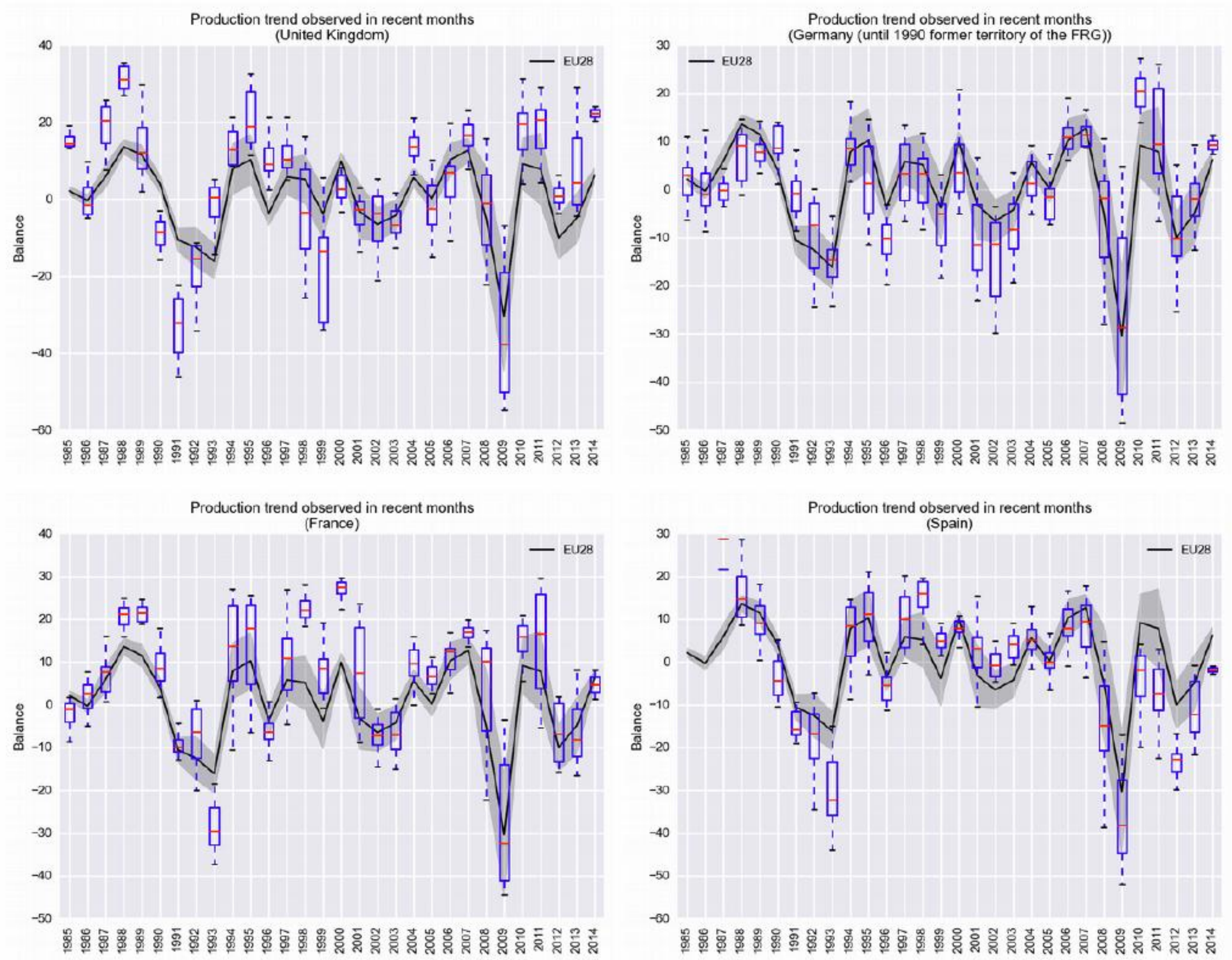

Fig. 11. Production trend observed in recent months from EUROSTAT (BS-IPT) for selected countries showing average over several years, as well as inter-annual variability (EU average = black line) over the period 1985 - 2014

Fig. 11 indicates that overarching economic trends drive the interannual variability and no distinct variations are visible throughout the year, with production levels remaining more or less stable. (Fig. 12). In addition, for most industrial production activities, a continuous production process can be assumed. Taking into account the diversity of the sector and the lack of temporal variability, the generic temporal profiles currently used in atmospheric models for weekly (Fig. 2) and diurnal (Fig. 3) variation, while keeping the annual variation constant, is likely sufficient. However, for local analyses, it may be relevant to assess emissions from a large industrial installation and its temporal operating patterns in more detail to assess its potential contribution to the local concentration field. On a national or European scale, the effort required to disaggregate emission sectors for modelling and to apply industry-specific temporal profiles appears not to be cost-effective at this stage.

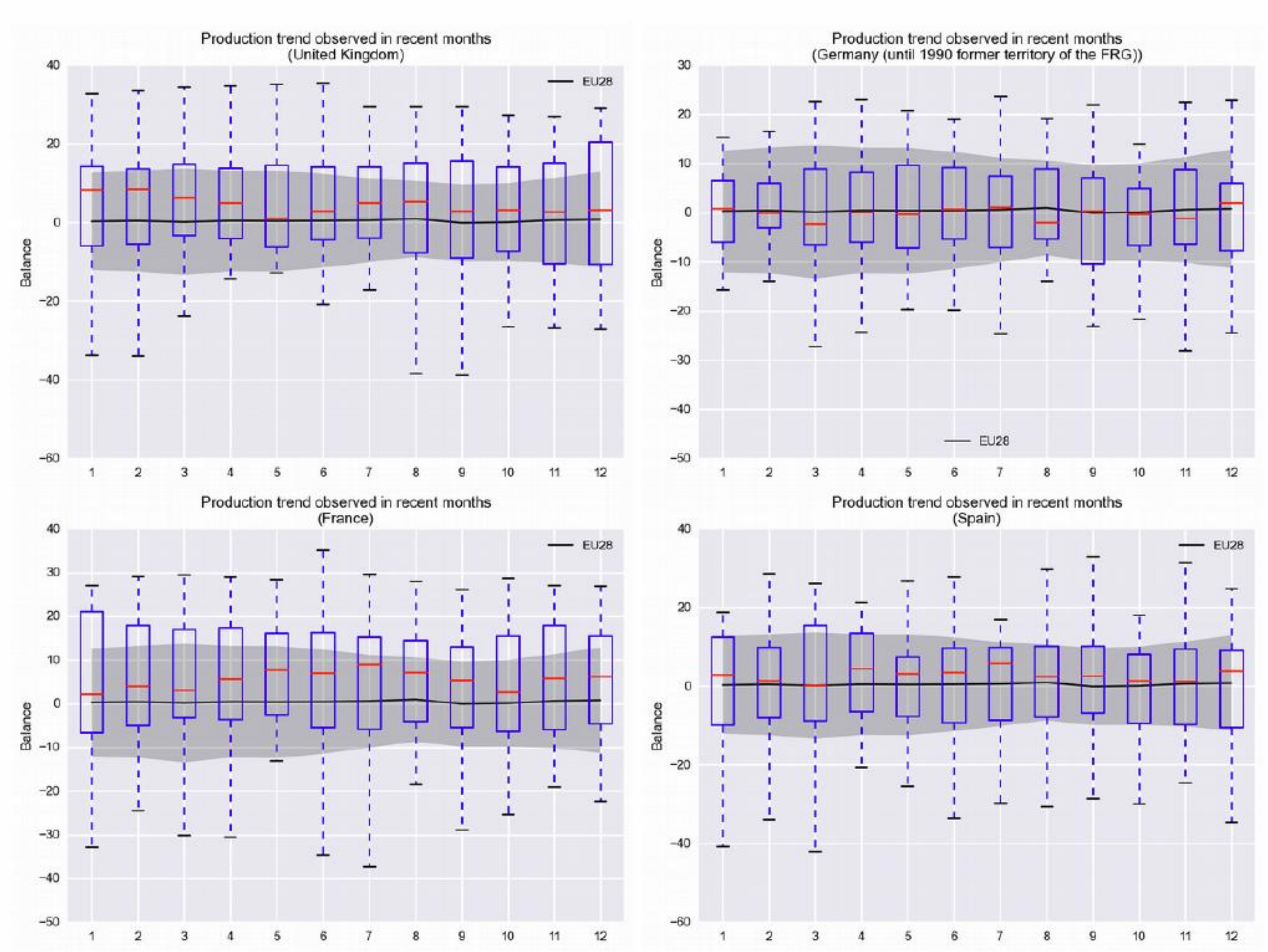

Fig. 12. Production trend observed in recent months as a monthly variation from EUROSTAT showing average over several years, as well as inter-annual variability (BS-IPT) for selected countries

Road transport (SNAP 7)

Road transport as a sector is one of the main contributing source sectors to a range of air pollutants, as well as showing marked temporal variations and is thus of particular interest. The contribution of different source-groups within this sector (passenger cars, light commercial vehicles, heavy duty vehicles and motorcycles) has been discussed in Reis et al. (2000) with regard to their contribution to air pollution levels. In spite of the importance of this sector, however, there has been no substantial work on temporal emission profiles in recent years. Developments have focused more on the improvement of emission factors, e.g. in the context of the UNECE Task Force on Emission Inventories and Projections and its Transport Panel and the development of the COPERT 4 emission model[6]. An inquiry to the Transport Panel (pers. comm. Leonidas Ntziachristos, panel chair) has

[6] http://www.eea.europa.eu/publications/copert-4-2014-estimating-emissions

confirmed that no recent or current activities are known to develop updated temporal profiles on a European scale. The most recent European scale study available which did include information on temporal emission profiles from road transport was the study "Development of a Database System for the Calculation of Indicators of Environmental Pressure Caused by Transport" within the TRENDS project (Transport and Environment Database System, Project funded by the European Commission

Directorate General for Transport and Energy, Contract No. B2000-B27040B-SI2.198159-SER ARISTOTLE). In the course of TRENDS, temporal and spatial disaggregation of vehicle emissions for the year 1995 was conducted for all EU 15 member states, however, only spring and summer seasonal data have been published. Further European-scale work has been conducted in the frame of COST Action 319 on "Methods of Estimation of Atmospheric Emissions from Transport", which concluded in 1999. Similar to TRENDS later, COST 319 did not develop specific datasets on temporal patterns of road transport emissions. Finally, in the EUROTRAC 2 GENEMIS project (Friedrich and Reis, 2004), several measurement campaigns investigated in-use emission factors, for instance conducting on-street or tunnel measurements, but did as well not focus on deriving temporal profiles.

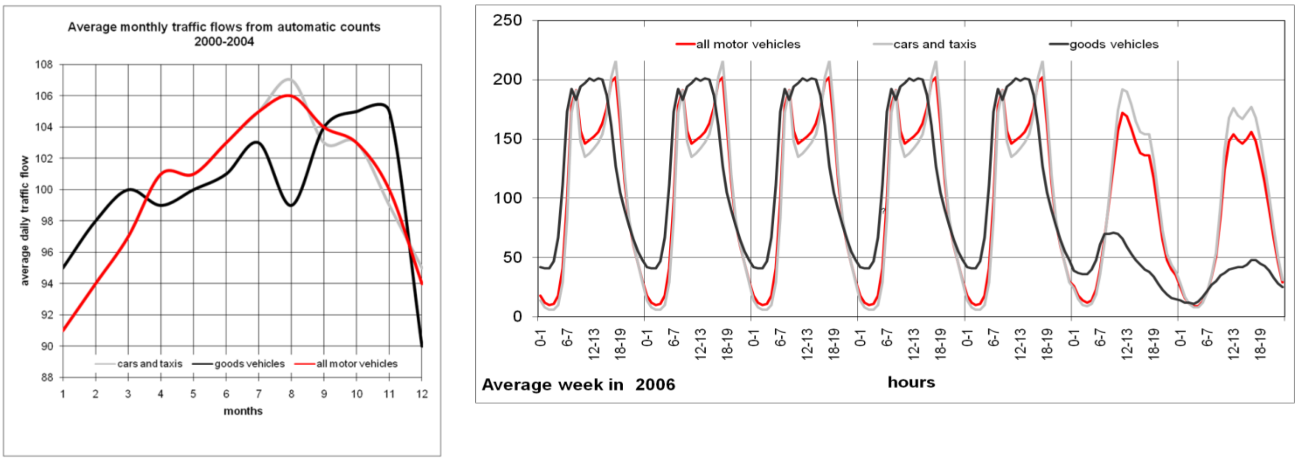

Fig. 13. Temporal profiles of road traffic flows based on traffic counts from the UK Department for Transport (DFT) averaged over the period of 2000 to 2004 showing annual variations (left) and weekly/diurnal variations (left) for cars & taxis, goods vehicles and all motor vehicles.

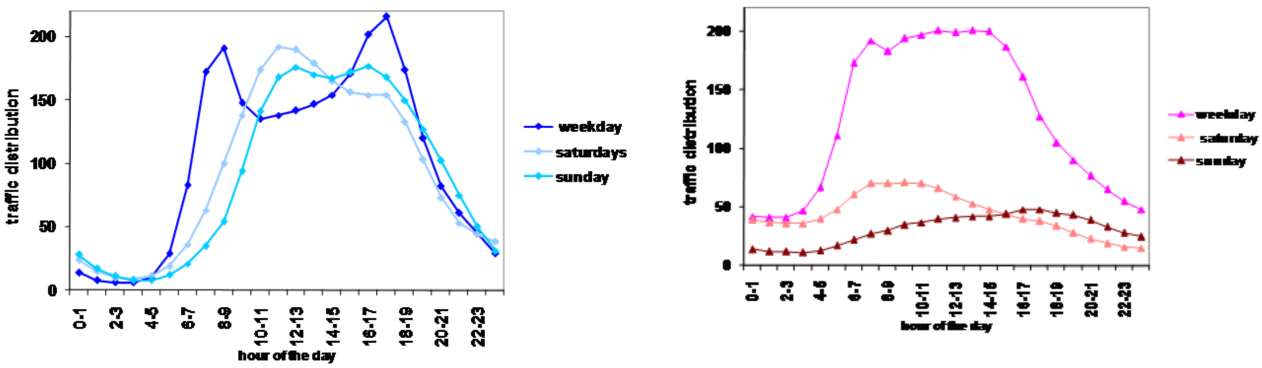

Fig. 14. Temporal profiles of road traffic flows based on traffic counts from the UK Department for Transport (DFT) averaged over the period of 2000 to 2004 showing diurnal variations for cars & taxis (left) and goods vehicles (right).

Analyses conducted based on data for the UK (Figs. 13 & 14) depicts similar diurnal peaks as shown in Fig. 3 due to the morning and afternoon/evening rush hours. Equally, Fig. 13 (right) indicates a slightly lower activity rate on weekend days compared to weekdays, as shown in Fig. 2. However, what the generic profiles do not pick up is the substantial difference between passenger and freight transport patterns, as well as the difference in diurnal patterns between weekdays and weekend days. In addition, the different annual patterns for passenger vehicles (peak in summer, likely due to holiday driving) and freight vehicles (dip in the summer, due to summer holidays), as well as the distinct annual curve of transport activity in the UK are not represented in the rather flat curve in Fig. 1.

Taking into account the substantial contribution of road emissions in particular in densely populated urban areas and along major roads and motorways, the effect of shifts in the timing of emissions from the sector overall will likely be significant when modelling with high spatial resolution. Due to the distinct differences between the type of day, as well as between passenger and freight transport activities, breaking down the source sector for modelling into sub-sectors (passenger cars, light duty vehicles, heavy duty vehicles and others) would be advised. In order to adequately account for the difference in weekday/weekend activities, implementing a calendar with national/local holidays would be beneficial, and the assessment of diurnal patterns should take account of local or regional working patterns. For instance, the typical working hours in the UK (9 a.m. - 5 p.m.) will differ from patterns in other countries, particularly in Southern Europe, and working patterns (and the resulting rush hour timing) may as well be seasonally different in the same country. While the latter is likely of less importance, the time-shift due to daylight savings time is already accounted for in the models and needs to be accounted for when generating specific road transport profiles.

Conclusions and recommendations for ECLAIRE modelling

The material presented in this deliverable illustrates a rather mixed picture with regard to recent research into, respectively data available for the temporal disaggregation of anthropogenic emissions for atmospheric modelling.

Taking into account the 'cost' related to sourcing data for temporal disaggregation, in particular the recurring data collection and processing, the general recommendations will distinguish the level of spatial resolution at which modelling occurs. This is in on the one hand in line with the hypothesis that the temporal emission profiles are more relevant where spatial resolution is high, i.e. the location of the source, the time steps of the transport and chemical transformation processes and other local conditions play more of a role than for large grid cells at regional/global scale. On the other hand, emission datasets at a lower spatial resolution (e.g. 10 km x 10 km, 50 km x 50 km and above) will represent a mixture of meteorological parameters and anthropogenic activities which are likely to blend together in a larger area, hence making the temporal profiles less relevant. However, the latter may not hold for grid cells which are strongly affected by sources with a high temporal variability (e.g. road transport in large urban areas, or intensive agriculture), where a response to seasonal or diurnal variations may be seen even at low spatial resolution.

General recommendations by source sector for ECLAIRE modelling activities on a **regional scale** proposed here are:

- **Power generation (SNAP 1):** Use the temporal profiles for monthly disaggregation as generated by the MACC project, or, as an alternative, to generate a profile for a specific country and year based on the EUROSTAT statistics of monthly electricity consumption (NSA_IS-CEL, see Fig. 7). Due to the clear temperature influence and regional difference as discussed above, the use of profiles for a specific year would likely yield better results than a generic profile. A split into different fuel types does not appear to be necessary, as base load coal fired power plants can be expected to mainly determine the shape of the temporal profile over the year. As base load plants are typically operating 24/7, generic profiles currently available from MACC for weekday/weekend differentiation, as well as for diurnal variation, should continue to be used, as no more detailed information could be identified that is readily available to improve these.
- **Residential combustion (SNAP 2):** Due to the strong relationship of residential combustion activities to ambient temperatures, as illustrated by Denier van der Gon et al. (2011) and Mues et al. (2014), best practice would be to include the degree-day based functions described in Mues et al. (2014) and already applied by Bessagnet et al. (2012, CHIMERE) and Simpson et al. (2012, EMEP). The advantage of a function-based approach in the model is that it allows for taking into account degree-day gradients across countries and regions, which are not otherwise easy to account for. In case no meteorological model output is immediately available, using EUROSTAT degree-day datasets on NUTS2 (NRG_ESDGR_A) level would provide a viable alternative and improvement over using country-level data, as substantial differences can be expected for heating degree days in different regions.
- **Industrial combustion & production processes (SNAP 3/4):** As no evidence has been found from available statistical data that would hint at profound differences or allow for the identification of improvements for these sectors, using the profiles presented in MACC is recommended.
- **Road Transport (SNAP 7):** Due to the distinct differences between the activity patterns of passenger cars on the one hand, and freight vehicles (light and heavy duty vehicles) on the other, it is recommended to disaggregate (at least) these two sub-sectors and their emissions, and to apply different temporal profiles to each. As the analysis for the UK highlights (Figs. 13 & 14; similar patterns can be assumed for other countries) the differences are visible on diurnal, weekly and monthly level, supporting an approach with different profiles for these two activity groups. This is particularly relevant, as the emissions contributed from both sub-sectors will likely have different compositions as well, with high NO_x emission shares from diesel vehicles (most light and heavy duty vehicles) and differences in VOC and PM between passenger and light/heavy duty vehicles. As this would potentially require a substantial effort to extend the emission handling within atmospheric models, an alternative solution would be to calculate a combined temporal profile based on both activity data and emission shares, which would – however – need to be weighted with the relative contribution to total emissions and hence be different for each pollutant and year. However, from comparing data from the UK with the existing profiles from MACC or LOTOS-EUROS, the difference appears to be substantial. A final decision on the best approach taken would likely be taken after exploratory modelling using profiles based on the UK transport activity data for a recent year and analysing the magnitude of the effect in comparison with kerbside monitoring sites.

In addition to these general recommendations by source sector for ECLAIRE modelling activities on a regional scale, for **local-scale** modelling (e.g. in Scotland and The Netherlands), the relevance of specific local sources should be considered. While it is time and resource consuming, an assessment of additional information (e.g. regarding automatic traffic counts providing a detailed temporal split of major road emissions in the area, or the type of fuel and load for a local power plant) for the domain where high resolution model runs are conducted could be beneficial. This could be particularly important in cases where model results and observations do not agree and the temporal emission patterns of a local source may be the cause of this divergence.

5. Milestones achieved

N/A

6. Deviations and reasons

Short delay in delivery of this document due to emerging literature and ongoing work on this topic in MACC and other projects.

7. Publications

N/A

8. Meetings

Attended ECLAIRE annual meetings in Brescia and Edinburgh, no specific meetings held for this Deliverable.

9. List of Documents/Annexes

ANNEX with data tables from EUROSTAT *(to be compiled after discussion with modellers on format and data needs)*

10. References

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